Gender Differences in Anterior Cruciate Ligament Injury Vary With Activity

Epidemiology of Anterior Cruciate Ligament Injuries in a Young, Athletic Population

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Background: Previous studies have shown that women involved in similar activities as men are at increased risk for anterior cruciate ligament injuries.

Hypothesis: The incidence rate of complete anterior cruciate ligament tears for men and women in our athletic, college-aged population is similar.

Study Design: Descriptive epidemiology study.

Methods: Students graduating in class years 1994 to 2003 at our institution who sustained complete anterior cruciate ligament tears were assessed for mechanism of injury and type of sport played at time of injury. We calculated the incidence proportion, an estimation of risk, by gender and class year, and the incidence proportion ratio comparing men and women by class year. We also calculated incidence rates by gender and type of sport played and incidence rate ratios comparing men and women.

Results: There were 353 anterior cruciate ligament injuries in the 10 classes studied. We found an overall, 4-year incidence proportion of 3.24 per 100 (95% confidence interval, 2.89-3.63) for men and 3.51 (95% confidence interval, 2.65-4.65) for women (incidence proportion ratio, 1.09 [95% confidence interval, 0.80-1.47]). The overall anterior cruciate ligament injury rate, excluding male-only sports, was significantly greater in women (incidence rate ratio, 1.51 [95% confidence interval, 1.03-2.21]). We found significantly greater injury rates among women in a gymnastics course (incidence rate ratio, 5.67 [95% confidence interval, 1.99-16.16]), indoor obstacle course test (incidence rate ratio, 3.72 [95% confidence interval, 1.25-11.10]), and basketball (incidence rate ratio, 2.42 [95% confidence interval, 1.05-5.59]).

Conclusion: We found little gender difference in the overall risk of an anterior cruciate ligament tear; however, there were gender differences in injury rates when specific sports and activities were compared and when male-only sports were removed from the overall rate assessment.

Keywords: ACL; epidemiology; military; gender

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In recent years, there has been a great deal of interest in anterior cruciate ligament (ACL) injuries in women athletes. Multiple studies have shown that women involved in similar activities as men are at increased risk for ACL injuries.[1,3,6,15] Most studies have shown that women in the military also demonstrate an increased risk.[2,5,10,13] For example, the United States Naval Academy found female midshipmen have a higher incidence of ACL tears than male midshipmen. In a 6-year review of midshipmen ACL injury data,[10] the relative risk of ACL injuries among women when compared with men was 2.44 ($P < .0001$). This same study also showed the rate ratio between male and female midshipmen to be 3.96 ($P = .006$), 1.40 ($P = .483$), and 9.74 ($P = .0005$) when considering injuries occurring during intercollegiate sports, intramural sports, and military training, respectively.

In contrast, at the United States Military Academy at West Point, we found a similar proportion of ACL reconstructions among male and female cadets during a 10-year period (1987-1997) (Taylor, unpublished data). To further explore these findings, we examined the incidence of ACL injuries among 10 consecutive graduating classes at our institution. For the purposes of prevention research, it is useful to first establish the incidence of injury and then develop and test prevention programs to evaluate changes in injury rates.[16] We therefore sought to 1) determine the individual risk of an ACL injury among male and female students at our institution, 2) to estimate the overall ACL injury rates among male and female students, and 3) to calculate sport and activity-specific injury rates for both genders.

MATERIALS AND METHODS

A cohort study was conducted to examine the epidemiology of ACL injuries at the United States Military Academy at West Point. Injury data were collected prospectively. Students graduating in class years 1994 to 2003 composed the study population.

Primary Data Collection

At our institution, all students are required to participate in organized physical activities, and if they are injured, they need an evaluation by a physician to be excused from activity. Students who sustained complete ACL tears and graduated in class years 1994 to 2003 were identified by an orthopaedic surgeon. The standard treatment protocol for all musculoskeletal problems among students at our institution includes an evaluation by an orthopaedic surgeon at either orthopaedic sick call or in athletic training rooms. Orthopaedic sick call is held Monday through Friday mornings before courses. Injuries may also be evaluated by an orthopaedic surgeon in athletic training rooms after intramural, club, or intercollegiate athletic activities. Therefore, any significant musculoskeletal injuries should be seen for evaluation and be documented by an orthopaedic surgeon shortly after injury.

Anterior cruciate ligament injuries were entered into 1 of 2 databases that were accessed for the purposes of this analysis. From 1990 to November 1996, all athlete injury data were entered into an internally developed Athlete Health Database. In November 1996, this database was replaced with a Department of Orthopaedics ACL Injury database using Microsoft Access. All ACL injury data were maintained in this database for the remainder of this study.

Diagnosis was based on history, physical examination, imaging, and/or arthroscopy. A complete ACL tear was defined as an acute ACL injury with associated laxity and subsequent confirmation of an ACL deficiency by arthroscopy or magnetic resonance imaging (MRI) evaluation. An orthopaedic surgeon coded ACL injuries as complete or partial tears. Only complete ACL tears were included in this analysis. Students with partial ACL injuries, defined as evidence on MRI imaging or at arthroscopy of ACL injury with >50% of the ACL fibers intact and no evidence of increased translation or rotational instability on physical examination, or those who had an ACL reconstruction before entering the institution and subsequently experienced a reinjury to the ACL while at our institution, were not included in this study. To ensure data reliability for this study, all database information was cross-referenced with inpatient records as well as with both the operating room and orthopaedic surgery service surgical logs. We are confident that we identified all clinically significant ACL injuries in this population throughout the duration of the study.

We recorded the activity, level of sport played at time of injury (intramural, club, intercollegiate, physical education (PE), military training, or free time), injury date, gender, class year, injured side, and date of surgery for each injury based on subject report and/or reports by physicians, athletic trainers, or physical therapists present at the time of injury. In addition, mechanism of injury (contact vs noncontact) was obtained and entered retrospectively into the database(s) for injuries before 1998 using clinic notes, operative notes, and inpatient records. Beginning in 1998, the mechanism of injury was entered into our Department of Orthopaedics database. Contact injuries were defined as an ACL injury resulting from contact to the body, and noncontact injuries were defined as an ACL injury resulting without contact to another person.

With respect to categorizing level of sport played at time of injury, those injuries that occurred during military training exercises were termed "military training." The Indoor Obstacle Course Training (IOCT) is run by the Department of Physical Education, and the level of sport for this activity was coded as "Physical Education." The category "free time" included activities during off-duty time such as free-time skiing.

Physical Activity Requirements

All students are required to participate in intramural, club, or intercollegiate sports in all but 2 semesters of their student career. Intercollegiate sports are those played at the Division I level. Intramural sports are similar to high school level of play, and club sports represent a level of play that is in between intercollegiate and intramural sports. Most intramural sports are mixed gender except for the exclusively male sports of boxing, football, wrestling, and rugby. Competitive clubs are also mostly mixed gender, although there are teams that are exclusively female (lacrosse and team handball) and male (wrestling, volleyball, boxing, rugby, water polo, and team handball). Women's club rugby was added in the spring of 2003. Intercollegiate athletic teams exist for both men and women in basketball, soccer, track, cross-country, swimming and diving, rifle, and tennis. Women have intercollegiate teams in volleyball and softball, while men have intercollegiate teams in baseball, football, sprint football, gymnastics, hockey, lacrosse, and wrestling. For these analyses, we combined sprint and traditional football injuries and exposures. Women comprise approximately 15% of the students; however, the number of women students in intercollegiate sports is disproportionately greater than the number of men (approximately 45% of women versus 30% of men).

In addition to participating in competitive sports, all students are required to participate in Department of Physical Education courses and activities, although some courses are male- or female-only courses. All first-year students must take a course called Military Gymnastics, which is unique to our institution and emphasizes agility, balance, vaulting, correct jumping and landing technique, as well as strength development. This course also teaches how to perform the IOCT. All students take the IOCT during the last 3 of their 4 years. Men and women perform the same test events, but grading scales are normalized by gender.

Finally, students participate in mandatory military training throughout their 4 years at the institution. Students participate in field-training exercises before their first and second academic years. These are 8-week courses of intense military and physical training. During the summers before their third and fourth years in school, students also participate in a variety of military training programs, which include attending airborne or air assault schools. The military requirements and physical activities are the same for both male and female students.

Analyses

Overall Summary Statistics. We present descriptive data for each of the risk factors of interest (gender, sport, mechanism of injury, level of sport, and year at the academy).

Incidence Proportions and Incidence Proportion Ratios. The incidence proportion (IP) is the proportion of a closed population at risk that becomes injured within a given period of time[14]; it is a valid estimator of personal injury risk.[12] The unit of analysis is the athlete, and the IP provides the average probability, across all athletes, that an athlete will be injured during a 4-year course of study at our institution.[12] Therefore, the numerator is the number of injured students, and the denominator is the number of students who are at risk.[12] In this analysis, the students at risk included any student at the institution in our study population during the study period. We assessed the proportion of male and female students at risk in each class that sustained a complete ACL injury during their 4 years at our institution per 100 athlete-years. (See Appendix, available in the online version of this article at http://ajsm.sagepub.com/cgi/content/full/35/10/1635/DC1/.) We determined the incidence proportion ratio (IPR) by assessing the ratio of the IP among female students compared with male students (referent) and present 95% confidence intervals (CIs) for these associations by class year.

Incidence Rates and Incidence Rate Ratios. The injury incidence rate (IR) is an instantaneous rate of development of injury in a population.[14] The numerator of the IR is the number of injuries that occur during 1 time period, and the denominator is the population at risk of experiencing the event during this period, expressed as person-time.

We defined the IR numerator as the number of new ACL tears that occurred during our study period and the denominator as athlete-exposures in the said time period. Incidence rates were calculated by sport and level of play, each by gender per 1000 athlete-exposures. One exposure was defined as 1 participation experience in a given course or activity (eg, practice, game, scrimmage). To estimate athlete-exposures, we evaluated the physical activity requirements for students and calculated the person-time at risk for each of these risk factors.

We present the incidence rates for each of the different levels of play (eg, intercollegiate, intramural, club) separately rather than in aggregate because of the nature of the different tiers of experience, talent, practice, and fitness within each level and so that readers can compare incidence rate data from their institution with the level-specific sport rates at our institution.

We used Poisson regression to estimate the rate of ACL injuries per 1000 athlete-exposures and computed incidence rate ratios (IRRs) for gender, using male gender as the referent category. We present IRR and 95% CI by sport type and level of sport. We also examined the IRR among strictly noncontact injuries.

Calculating Person-Time at Risk. To determine the total person-time at risk by sport and level of play, we obtained attendance records and exposure-time information by level of sport and type of sport between 1990 and 2003. See Appendix, available in the online version of this article at http://ajsm.sagepub.com/cgi/content/full/35/10/1635/DC1/.

When calculating the IRR, if there were no injuries across all levels of sport for a particular sport, we did not include this sport in our final exposure dataset. In addition, if an injury occurred during free time or the sport and level of sport played at the time of injury were missing, we excluded these injuries from our IR analyses and included them only in our IP analyses. Furthermore, because military training exposure was not available, we did not include military training injuries in our IR analyses and included them only in our IP analyses. For these reasons, the number of injuries varies between the IR and IP analyses.

RESULTS

Summary Statistics

Between these 10 classes, a total of 11 340 students entered our institution, and a total of 9498 graduated (Table 1). Therefore, for the purposes of this study, our patient population was 10 419 students (9023 males, 1396 females) that attended our institution, each for a 4-year college career. The mean class size was 1042, with an average of 140 (13.4%) female and 902 male (86.6%) students in each class. There were 353 ACL injuries, 292 among male students and 49 among female students (Table 1). There were 12 students who injured both knees during their 4 years at the institution, 10 men and 2 women. The average number of ACL injuries per class was 30.2 (range, 16-41) for men and 5.1 (range, 1-9) for women.

The greatest number of injuries among male students occurred in football (34.8%), rugby (15.2%), and basketball (8.3%) and among female students in basketball (17.6%), the gymnastics course (13.7%), soccer (9.8%), and the indoor obstacle course (9.8%) (Table 2). Data on the association of a contact injury with an ACL tear were available for 309 (87.5%) of the 353 ACL injuries. Of the 44 missing data points, 4 were among female students, and 40 were among male students. Of those with complete data, most ACL tears were noncontact (67.2% among men; 89.4% among women) (Table 2). Noncontact injuries among men were concentrated in football (31.8%), rugby (10.8%), basketball (10.8%), and skiing (10.2%), while most of the noncontact injuries among women occurred playing basketball (19.1%), in the gymnastics course (16.7%), and on the obstacle course (11.9%).

Injuries occurred at all levels of play. Thirty-five percent of the injuries occurred playing intramural sports (n = 123), 25.2% occurred during intercollegiate sports (n = 89), 13.9% during PE instruction (n = 49), 9.6% during club sports (n = 34), 11.6% during free-time activity (n = 41), 3.4% during military training (n = 12), and 1.4% were missing the activity or level of sport played at time of injury (n = 5). Among the 12 injuries that occurred during military training, all but 2 occurred during the summer months when students are conducting military training exercises.

Incidence Proportion Analysis

There were 341 injured students during the study period. Overall, the 4-year IP was 3.24 per 100 (95% CI, 2.89-3.63) for men and 3.51 per 100 (95% CI, 2.65-4.65) for women; the overall female to male IPR was 1.09 (95% CI, 0.80-1.47). The IP per 4-year student career by class year between male and female students was significantly different for only 1 class, 1999 (IPR, 2.49; 95% CI, 1.15-5.42) (Table 3). Otherwise, the IP between male and female students was similar across all years.

Incidence Rates

The injury rate analyses (after excluding injuries as outlined in Methods) included 295 injuries (n = 256 male; n = 39 female). Overall, the ACL IR was 0.117 (95% CI, 0.10-0.13) per 1000 athlete-exposures among men and 0.095 (95% CI, 0.07-0.13) per 1000 athlete-exposures among women, for a female-to-male IRR of 0.82 (95% CI, 0.58-1.15). Within level and type of sport, the largest difference observed between male and female students was on the IOCT (P = .019) and in PE gymnastics (P = .001) (Tables A1-A4). (These tables can be seen online in Appendix A at http://ajsm.sagepub.com/cgi/content/full/35/10/1635/DC1).

TABLE 1
Student Population and the Number of ACL Tears for Class Years 1994-2003

Class Year	Started	Graduated	Average[a]	Total ACL Tears[b]
1994				
Male	1067	919	993	41
Female	148	127	137.5	6
1995				
Male	1032	886	959	29
Female	149	129	139	4
1996				
Male	981	833	907	37[c]
Female	119	92	105.5	1
1997				
Male	996	819	907.5	33
Female	122	98	110	4
1998				
Male	917	781	849	32[c]
Female	132	102	117	2
1999				
Male	954	820	887	23[c]
Female	162	129	145.5	9
2000				
Male	953	822	887.5	30[c]
Female	177	143	160	7
2001				
Male	968	783	875.5	35[c]
Female	177	147	162	9[c]
2002				
Male	1012	838	925	26[c]
Female	179	151	165	5
2003				
Male	922	744	833	16[c]
Female	173	135	154	4
Total	11 340	9498	10 419	353

[a]Number on first day of academics + graduated by class/2.
[b]Includes all tears, not total athletes with a single or contralateral tear. There were 12 contralateral tears.
[c]There were 36 male athletes injured in 1996, 30 in 1998, 22 in 1999, 29 in 2000, 33 in 2001, 25 in 2002, and 14 in 2003. There were 7 injured female athletes in 2001.

Because the majority of male injuries occurred in football, rugby, and wrestling, 3 male-only sports until the spring of 2003 (when women's rugby became a sport), we examined the overall ACL IRR between men and women after excluding injuries and exposure time for these male-only sports. The IR among men was 0.06 (95% CI, 0.05-0.08) per 1000 athlete-exposures, and the female-to-male IRR was 1.51 (95% CI, 1.03-2.21). While there are women-only sports such as softball, we did not exclude the exposures experienced by women playing this sport because we thought that the male-only sport of baseball was similar in nature for comparison and furthermore, there were some male exposures to softball during intramurals.

In intercollegiate sports, the highest rate of ACL injury was observed among women in basketball (IR, 0.39 [95% CI, 0.18-0.87] per 1000 athlete-exposures) and among men in lacrosse and football (IR, 0.20 [95% CI, 0.10-0.41] and IR, 0.23 [95% CI, 0.18-0.31] per 1000 athlete-exposures, respectively).

TABLE 2
Total Number (%) of ACL Injuries by Sport, Gender, and Type of Injury[a]

	Type of Female ACL Injuries (%)[b]		Type of Male ACL Injuries (%)[b]		Total ACL Injuries (%)	
Sport/Activity	Contact, n (%)	Noncontact, n (%)	Contact, n (%)	Noncontact, n (%)	Women, n (%)	Men, n (%)
Baseball	n/a	n/a	0	1 (0.6)	0	1 (0.3)
Basketball	0	8 (19.1)	4 (4.7)	19 (10.8)	9 (17.6)	25 (8.3)
Boxing	n/a	n/a	1 (1.2)	2 (1.1)	0	3 (1.0)
CQC	0	0	1 (1.2)	0	0	2 (0.7)
Football[c]	1 (20.0)	0	38 (44.2)	56 (31.8)	1 (2.0)	105 (34.8)
Gymnastics	0	7 (16.7)	0	8 (4.6)	7 (13.7)	8 (2.7)
Team handball	0	4 (9.5)	1 (1.2)	4 (2.3)	4 (7.8)	7 (2.3)
Hockey	0	0	1 (1.2)	0	0	2 (0.7)
IOCT	0	5 (11.9)	0	9 (5.1)	5 (9.8)	9 (3.0)
Judo	1 (20.0)	0	2 (2.3)	2 (1.1)	1 (2.0)	5 (1.7)
Lacrosse	0	0	1 (1.2)	4 (2.3)	0	8 (2.7)
Military training	0	3 (7.1)	1 (1.2)	5 (2.8)	4 (7.8)	8 (2.7)
Cheerleading	0	2 (4.8)	0	2 (1.1)	2 (3.9)	2 (0.7)
Rugby	0	0	18 (20.9)	19 (10.8)	0	46 (15.2)
Skiing	0	3 (7.1)	1 (1.2)	18 (10.2)	3 (5.9)	19 (6.3)
Soccer	1 (20.0)	4 (9.5)	5 (5.8)	11 (6.3)	5 (9.8)	21 (7.0)
Track	0	2 (4.8)	0	0	2 (3.9)	0
Volleyball	0	2 (4.8)	0	2 (1.1)	2 (3.9)	2 (0.7)
Wrestling	n/a	n/a	11 (12.8)	9 (5.1)	0	22 (7.3)
Other[d]	2 (40.0)	2 (4.8)	1 (1.2)	5 (2.8)	4 (7.8)	7 (2.3)
Missing activity	0	0	0	0	2 (3.9)	0
Total	5	42	86	176	51	302

[a]ACL, anterior cruciate ligament; CQC, close quarters combat; IOCT, indoor obstacle course test; n/a, not applicable.
[b]Type of injury (contact vs noncontact) was available for 309 of the 353 total injuries, and therefore the numbers in the total ACL injuries columns do not equal those in the type of ACL injury columns. Totals in each row include free-time activities for which exposure data are not available, and therefore not all injuries in Table 2 were used to calculate incidence rates.
[c]Football among females included only powder-puff football.
[d]Other includes fencing, flickerball, parachuting, frisbee, horseback riding, concert-going, and motor vehicle accident.

TABLE 3
4-Year IP (per 100 Student-Years) by Gender and Class Year and IPR[a]

Class Year	Male IP (95% CI)	Female IP (95% CI)	IPR (95% CI)[b]	*P* Value
1994	4.13 (3.04-5.61)	4.36 (1.96-9.71)	1.06 (0.45-2.49)	.90
1995	3.02 (2.10-4.35)	2.88 (1.08-7.67)	0.95 (0.33-2.71)	.93
1996	3.97 (2.86-5.50)	0.95 (0.13-6.73)	0.24 (0.03-1.74)	.16
1997	3.64 (2.59-5.11)	3.64 (1.36-9.69)	1.0 (0.35-2.82)	1.0
1998	3.53 (2.47-5.05)	1.71 (0.43-6.83)	0.48 (0.12-2.02)	.32
1999	2.48 (1.63-3.78)	6.19 (3.22-11.89)	2.49 (1.15-5.42)	.02
2000	3.27 (2.27-4.70)	4.38 (2.09-9.18)	1.34 (0.59-3.06)	.49
2001	3.77 (2.68-5.30)	4.32 (2.06-9.06)	1.15 (0.51-2.59)	.74
2002	2.70 (1.83-4.00)	3.03 (1.26-7.28)	1.12 (0.43-2.93)	.82
2003	1.68 (1.00-2.84)	2.60 (0.97-6.92)	1.55 (0.51-4.70)	.44
Overall	3.24 (2.89-3.63)	3.51 (2.65-4.65)	1.09 (0.80-1.47)	.60

[a]IP, incidence proportions; IPR, incidence proportion ratios.
[b]Referent was male.

In PE courses, the greatest rates were observed on the IOCT among male and female students (IR, 0.25 [95% CI, 0.13-0.49] and 0.94 [95% CI, 0.39-2.26] per 1000 athlete-exposures, respectively). The IR between males and females were significantly different only on the IOCT, 3.72 (95% CI, 1.25-11.10) and in the gymnastics course, 5.67 (95% CI, 1.99-16.16).

In intramural sports, men playing football and rugby had the highest rates of injury (IR, 0.40 [95% CI, 0.31-0.53] and 0.49 [95% CI, 0.35-0.70] per 1000 athlete-exposures, respectively).

When we aggregated the exposures by sport for each gender (eg, aggregate exposure and injury for intramural basketball, PE basketball, and intercollegiate basketball), we found the female-to-male IRR was 2.42 (95% CI, 1.05-5.59) for basketball, 0.84 (95% CI, 0.31-2.24) for soccer, 1.14 (95% CI, 0.29-3.34) for team handball, and 2.57 (95% CI, 0.36-18.24) for volleyball. While rugby, hockey, and baseball/softball were played by both genders, there were no injuries between both genders in these sports, and therefore we could not determine overall incidence rates. We did not attempt to determine the aggregate IR for football because the 1 football injury reported in a woman occurred during participation in a women-only, once-a-year game of flag football and, therefore, is not similar in nature to the playing experienced by men playing football.

When we limited the analysis to noncontact injuries, we found the overall noncontact ACL IR among men (n = 142) was 0.07 (95% CI, 0.05-0.08) per 1000 athlete-exposures and 0.09 (95% CI, 0.06-0.12) per 1000 athlete-exposures among women (n = 35), for an overall female-to-male IRR of 1.32 (95% CI, 0.91-1.92). When aggregating noncontact injuries and all exposures across the different levels of play, we found the female-to-male IRR for noncontact ACL injury was 3.01 (95% CI, 1.19-7.63) for basketball, 3.72 (95% CI, 1.25-11.10) on the obstacle course test, 4.96 (95% CI, 1.80-13.67) in gymnastics, 1.71 (95% CI, 0.43-6.83) for handball, and 1.27 (95% CI, 0.40-4.05) for soccer.

DISCUSSION

Concern about ACL injuries in women has been heightened in recent years as reports document greater numbers of ACL injuries in women athletes when compared with men. For example, Arendt and Dick[1] found that during a 5-year period, the IR of ACL injuries in collegiate female soccer players was 2.4 times that of their male counterparts, and the rate was 4.1 times greater in female basketball players when compared with male players. Bjordal et al[3] found that the IR of ACL injuries in women soccer players was twice that of men soccer players. Similarly, Gwinn et al[10] found an IRR of 9.48 (*P* = .02) when comparing male and female intercollegiate soccer players and 6.86 (*P* = .04) when comparing male and female intramural soccer players. Other studies show similar sport-specific trends.[7,9]

In this study, we have presented both the 4-year risk of ACL injury and the overall and sport-specific rate(s) of ACL injury in this population. We found the IP, which estimates a student's average probability of injury during 4 years and is a valid estimator of personal injury risk,[12] was similar between men and women (IPR, 1.09 [95% CI, 0.80-1.47]) in our population. At the United States Naval Academy, Gwinn et al[10] found there was a 2.44 times greater risk of injury among female midshipmen than male midshipmen (*P* = .0001). The difference in individual risk between men and women in these 2 populations is a result of a slightly decreased risk among male midshipmen when compared with male cadets at West Point (0.0055 vs 0.0081 risk per male per year) and a greater risk among female midshipmen compared with female cadets at our institution (0.0135 vs 0.0088 risk per female per year). This may be due to an increase in the number of injuries in a specific activity or sport in which training or competition level is different between the 2 institutions. To discern this information, it is necessary to consider the rates of injuries within sport and activity.

Overall, when sport and activity groups were combined, we found no significant difference in the IR of ACL tears, a measure of the injury per unit of exposure, between male and female students (IRR, 0.82 [95% CI, 0.58-1.15]). However, we did discover statistically significant gender differences when specific activities and sports were aggregated and compared and in the overall IR when injuries and exposures occurring in male-only sports were excluded from the analysis (IRR, 1.51 [95% CI, 1.03-2.21]).

We found the rate of ACL injury among female students was 2.4 times greater than among male students in basketball (*P* = .04) when we aggregated across all levels of play. This finding, albeit smaller than that reported by Arendt and Dick,[1] supports their finding of a 4 times greater rate of injury among women than men. However, we were not able to compare only our intercollegiate basketball data with their data, which is intercollegiate-specific, since there were not any ACL injuries among male students playing intercollegiate basketball at our institution during our study period. Unlike Arendt and Dick,[1] however, we did not find significant differences between men and women in soccer at either the aggregate level or at the intercollegiate level. Our findings were also not consistent with Gwinn et al[10] in that the IRR was not greater among female soccer players at the intercollegiate level, the intramural level, and/or in aggregate form. In fact, we did not find a significant difference for soccer, volleyball, or handball at any level and/or in aggregate form.

We did find statistically significant differences in the PE gymnastics course (*P* = .001) and the IOCT (*P* = .02), which are institution-specific activities, with increased rates among women of 5.7 and 3.7 times, respectively. Gwinn et al[10] also found an increased rate of injury for women on the obstacle course when compared with men, although they found the rate to be 10.85 times higher (*P* = .004). The reason for the difference in the magnitude of the injury rate between the United States Naval Academy and our institution on the obstacle course may be due to the difference in the obstacle course itself and perhaps the training that is provided before attempting the obstacle course at the different institutions. At our institution, the students are required to take the PE gymnastics course during their first year and are taught how to perform the obstacle course in PE gymnastics. The gymnastics course promotes a physical training program that incorporates both proprioception-balance and plyometric-agility training components that are similar to published ACL injury preventive training programs.[4,11] Skills emphasized are agility, balance, vaulting, correct jumping and landing technique, as well as strength development. Additionally, each event on the obstacle course is taught before combining the events for testing on the IOCT. This type of pretest training on the obstacle course was not present for those studied in the US Naval Academy ACL injury study.[10] Therefore it is possible that differences in physical training programs at our institution and the Naval Academy influence the differences in ACL rates observed. However, even with training at our institution, the rates of injury among female students in the gymnastics course (where IOCT techniques are taught) and the IOCT itself are still significantly greater than that of male students. It is therefore likely that there are other intrinsic and/or extrinsic risk factors at play that are causing the increase among female athletes.

The overall injury rate for men is heavily weighted by injuries from football, wrestling, and rugby, which are male-only sports at our institution. When these sports were removed, the overall ACL injury rate was significantly greater in women (1.51 [95% CI, 1.03-2.21]). This is likely a better estimate for the comparison of overall rates between men and women since we found that 35% of the injuries in men were from football, 15% were from rugby, and 7% were from wrestling. The rate of injuries among men in these sports is extremely high, especially in intramural rugby (0.49), football (0.40), and intercollegiate football (0.23). Therefore, the estimate that included these male-only sports would be heavily weighted by the higher rates of injury in sports in which women do not participate.

When we limited our analysis to noncontact injuries, which may allow for a more direct comparison between male and female intrinsic risk factors, we found the female-to-male IRR for noncontact ACL injury was 3.01 (95% CI, 1.19-7.63) for basketball, 3.72 (95% CI, 1.25-11.10) on the obstacle course test, and 4.96 (95% CI, 1.80-13.67) in gymnastics. These were, again, the only activities for which significant differences were discovered, and these findings are consistent with our analyses including all injuries.

We elected to remove the exposures associated with sports for which there were no injuries during the study period when calculating the overall incidence rates. Therefore, we excluded 6 PE courses, 3 intercollegiate sports, 5 intramural sports, and 12 club sports. Excluded sports included crew, cycling, marathon, Tae Kwon Do, equestrian, mountaineering, orienteering, weight lifting, sailing, downhill and cross-country skiing, triathlon, racquetball, walleyball, swimming, cross-country running, tennis, skating, rock climbing, and self-defense. We believe the removals were justified for our population since there were no injuries in these sports for 13 years.

There are several strengths to this study. The ACL injuries were collected prospectively in 10 graduating classes providing a large number of injuries for statistical inference. Single-year studies are but a brief window of injuries. For example, if only the year 2003 was studied, we would have recorded less than one half the annual number of injuries in 1994 or 2001 (Table 1). In addition, because of the nature of a service academy, we feel confident we captured all ACL injuries during the study period and did not underreport the rates from missed injuries. Finally, we were able to determine the incidence of injury per unit of exposure using the records kept by the military academy.

Despite these strengths, this study has some limitations. We used retrospective exposure data and at times extrapolated the exposures from year to year when the actual exposures for a given year were not available. If we have overestimated exposures, then we have underestimated our IRs. Similarly, if we have underestimated exposures, we have overestimated our IRs. In addition, the age of the subjects in this study may represent fewer injuries than seen in a younger athletic population. Many of the studies on ACL injury rates focus on college-aged athletes, for example, Arendt and Dick,[1] but the college-age athlete is past the peak in age of the greatest number of injuries reported by applicants for part 2 of the board certification process from the American Board of Orthopaedic Surgery.[8] Therefore, a study focusing on the middle school– and high school–aged athlete might show different results. In addition, it may be difficult to generalize these data to the traditional collegiate-aged population because the military athlete population is very different, making comparisons sometimes difficult.

CONCLUSION

This study provides a broad picture of the individual risk of ACL injury and the rates of injury in various athletic events for men and women in our active, college-aged population. In this population, there is little difference in the individual risk of an ACL tear between men and women during their 4-year college career. However, we found gender differences in injury rates when specific sports and activities were compared and when male-only sports were removed from the overall rate assessment.

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